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Original Research

Magnetic resonance elastography for assessment of testicular stiffness in patients with varicocele

Testis MR elastography

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Abstract

Aim: The purpose of this study was to evaluate the stiffness and volume of the testes in adult patients with varicocele using Doppler ultrasonography (DUS) and magnetic resonance elastography (MR-E), and to compare the findings to those from the patients with normal contralateral testes and those from healthy controls.

Material and Methods: A prospective comparison research with 46 varicocele patients (92 testes) and 46 control patients (92 testes) was ethically authorized. There were 92 healthy control testes in Group III, 40 healthy contralateral testes in Group II, and a total of 52 testes with varicocele in Group I. Group comparisons were made using one-way analysis of variance (ANOVA), and binary comparisons were made using Student's t-test. Using Pearson's correlation test, the relationship between testicular stiffness and volume was investigated.

Results: The mean MR-E stiffness values did not significantly differ between the two groups or the three groups (P 0.05). The mean testicular volume varied significantly between groups I and III (P = 0.022). The difference between groups I and II (P = 0.716) and groups II and III (P = 0.074) did not, however, differ significantly. In any group, there was no statistically significant relationship between testicular volume and stiffness.

Discussion: Testicular volume or varicocele was not significantly correlated with MR-E readings. The accuracy of MR-E in predicting testicular parenchymal injury requires further research with larger patient groups.

Keywords

Elastography, Magnetic Resonance, Stiffness, Varicocele

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Introduction

A varicocele is an abnormal dilation of the pampiniform plexus veins. Common clinical symptoms include pain and a soft, palpable lump in the scrotum. In addition, the most typical reason for infertility in male patients is varicocele. It affects 15% to 20% of the general population [1]. With initial infertility, the prevalence rises to 35–44%, and with secondary infertility, it rises to 48–81% [2]. In situations of primary infertility, the prevalence rises to 35–44%, and in cases of secondary infertility, it rises to 48–81% [3]. Previous research has shown that varicocele has a deleterious impact on testicular volume [4,5]. The main reason for varicocelectomy in teenagers is testicular atrophy brought on by varicocele [5]. Most persons with varicocele have a varicocele on their left side because of the steep angle between the left spermatic vein and left renal vein [6]. Doppler ultrasonography (DUS) is frequently utilized as a basic imaging modality, especially in cases with subclinical varicocele, despite the fact that clinical evaluation is the primary diagnostic technique. Diagnostic criteria include vein enlargement to a diameter of more than 2 mm and increased vein width during the Valsalva maneuver [7,8].

Magnetic resonance elastography (MR-E), a phase contrast-based magnetic resonance imaging (MRI) technology, uses images of moving mechanical waves to provide quantitative images that reveal material properties like shear modulus [9]. Particularly for the early detection and grading of liver fibrosis, MR-E is now employed. Other organ disorders can also be detected with ultrasound elastography [10]. As new research applications are studied, there are increasingly more MR-E and elastography articles published each year [11].

Testicular parenchymal injury brought on by varicocele may have an impact on parenchymal stiffness. To assess the potential parenchymal effects of varicocele, parenchymal stiffness represented as stiffness may be relevant. In various studies on the effect of varicocele on the testicular parenchyma, it was found that varicocele altered testicular stiffness as measured by elastography. DUS and ultrasound shear wave elastography (SWE) were used in all investigations [12-17].

In this investigation, variations in testicular stiffness were assessed by MR-E in adult patients with varicocele, and the outcomes were compared to those of normal testes and healthy contralateral testes in the control group of patients without varicocele. Additionally, the relationship between differences in testicular volume and varicocele was evaluated.

Material and Methods

The Medical Ethics Committee approval was obtained for this prospective, controlled study (approval date and protocol No: 2023-08-14 and 2023/33-13). Each patient signed a written informed consent form and received full explanations of the MR-E before giving their consent.

Study population and design

Data from 46 patients with varicocele who underwent scrotal DUS examination in our hospital's radiology department between January 2022 and August 2023, as well as 46 healthy controls, served as the basis for our study. The study included 46 healthy individuals who were referred for scrotal MRI and MR-E in August 2023, as well as varicocele patients who had not undergone surgical treatment. Male sex and age greater than 18 were requirements for admission. Ten subjects were excluded from this study because of cryptorchidism, infection, hydrocele, pyocele, abnormal testicular parenchymal echogenicity on US examination, or a history of varicocelectomy. The study included a total of 46 varicocele patients (92 testes) and 46 controls (92 testes). Bilateral varicoceles affected six cases. Fifty-two varicocele-affected testes, their 40 healthy opposite-side testes, and 92 healthy control testes were added to Group I, Group II, and Group III, respectively. The participants in the control group who had sought advice about the scrotal US were randomly selected as healthy individuals.

Ultrasonography and Doppler examination

Scrotal US and DUS were carried out by two radiologists with a combined experience of more than seven years. Each radiologist evaluated each modality independently while undergoing a comparable number of exams. A high-frequency (9 MHz) linear probe from a US device (the General Electric (GE) brand Logic S8 model (2019)) was used for each evaluation. The pampiniform plexus veins were evaluated in both supine and upright positions, with and without the Valsalva technique. When the pampiniform plexus veins expanded and dilated to a width of more than 2 mm during the Valsalva maneuver, varicocele was identified (Figure 1). The side of varicocele (if present) was first noted [7-8]. Additionally, three dimensions of each testis were measured using light pressure in the supine position, and testicular volume was calculated by the US machine using the following formula based on analogous past investigations [13-17]. Based on comparable past studies, the US device evaluated testicular volume using the following methodology: In milliliters (ml), the volume of the testis is equal to breadth times length times height times 0.523 [13,18].

MRI and MR-E protocols assessment

All MR-E examinations were performed on a 3 Tesla General Electric Signa Architect MR scanner using commercially available software and hardware (GE Healthcare, Waukesha, WI, USA and Resoundant Inc., Rochester, MN, USA) [19,20]. Technically, there are two non-standard extra hardware apparatuses in MR devices: a special device called a passive driver and another device called an active drive for elastography. A torso coil was placed on each subject's body at the level of area of interest 6, with the subjects lying face down and head first (Figure 1). Outside the MRI room, mechanical shear waves were produced at 60 Hz using an active driving system. Mechanical vibrations from the active transducer were transmitted to the body through a stiff passive driver that was fastened to the anterior wall of the pelvis. The typical tool utilized in the FDA-approved commercially available MR-E technology implementation is a rigid driver. An expert MRI technician performed the MR-E examinations used in this investigation.

A motion-sensitized imaging sequence was used to observe the shear waves as they moved around space. A spin-echo echo planar imaging sequence was used to acquire axial wave images with the following parameters:

-Repetition time /echo time (ms), 50/23;
-Continuous sinusoidal vibration, 60 Hz; field of view, 32-42 cm
-Matrix size, 256 × 64; flip angle), 30°;
-Slice thickness, 10 mm; 4 evenly spaced phase offsets;

-4 pairs of 60 Hz trapezoidal motion-encoding gradients with zeroth and first moment nulling along the through-plane direction [19].

All processing processes were carried out automatically without any operator input to generate quantitative images of tissue shear stiffness in kilopascals. Staff radiologists at the Department of Radiology interpreted the MR elastographic images.

MRI-Touch, a commercially available program, was used to create magnitude, phase, and wave maps from MR-E images [19,20]. Six relative stiffness pictures were reconstructed for each slice position. Stiffness values (or elastograms) in the Pascals were assessed using ROIs in the muscle on anatomical T1 images and transferred into MR-E stiffness maps (Figure 2).

Statistical analyses

For the mean age, testicular volume, and MR-E values of the three groups, the findings were presented as the mean standard deviation (SD). Levene's test was used to assess the homogeneity of variances based on mean SD values. Binary comparisons of the groups were carried out using Student's t-test, and parametric analysis of variance (one-way ANOVA) was used to analyze the three groups. The association between testicular stiffness and volume was investigated using the Pearson correlation test (Pearson correlation coefficient = r). All statistical analyses were performed using SPSS (version 27.0, IBM Corp., Armonk, New York, USA), and statistical significance was defined as a P-value less than 0.05 within a 95% confidence interval (CI).

Ethical Approval

Ethics Committee approval was obtained.

Results

Ninety-two male patients, with a total of 184 testes included in the study, met these criteria. Of the 46 patients with varicocele on the left side, eight (13.04 percent, or 6/46) had it on both sides. There was no solitary right-sided varicocele in any of the cases. In total, 52 varicocele-containing testes were included in Group I, while 40 of these individuals' contralateral, healthy testes were included in Group II. Lastly, there were 46 people (92 testes) in Group III who were healthy bilateral controls.

Recurrent chronic discomfort in the scrotum or a palpable soft scrotal lump, which implies dilated veins, was the predominant symptom in symptomatic patients. The major focus of the evaluation of asymptomatic subjects is their reproductive health.

Group I had a mean age of 30.2 ± 9.1 years (24-51), Group II a mean age of 33.6 ± 9.5 years (19-49), and Group III, the control group, had a mean age of 34.4 ± 11 years (18-47). Age differences among the three groups were not statistically significant (P = 0.645). The main symptom in symptomatic patients was recurrent chronic pain in the scrotum or a palpable soft scrotal lump, which suggests dilated veins. The evaluation of asymptomatic people places a lot of emphasis on their reproductive health.

The average testicular capacity was 15.1± 3.09 ml in Group I, 15± 4.31 ml in Group II, and 16.5±4.45 ml in Group III (P = 0.333). The variations were uniform. There was no distinguishable difference between the three groups, despite the fact that mean testicular volume values in Group I were slightly lower than those of the other groups (P = 0.063). In addition, Groups I and III showed a statistically significant difference (P = 0.022). But, there was no statistically significant difference between the Groups II and III (P = 0.074). Similarly, there was no statistically significant difference between Groups II and I (P = 0.716).

No significant correlation between testicular stiffness and volume could be found using the Pearson correlation test for any of the three groups (r = −0.030, P = 0.436 for Group I, 0.055, P = 0.496 for Group II, and r= −0.086, P = 0.218 for Group III).

The MR-E values for Groups I, II, and III were 5402.15±223.12 Pa, 6453.11±198.13 Pa, and 7947.12±207.15 Pa, respectively. (P = 0.083) The variances were homogeneous. The mean MR-E values in the three groups did not differ significantly from one another (P = 0.273, f = 1.043). Between the two groups, there was no discernible difference (P = 0.195 for Groups I–II, 0.260 for Groups B–C, and 0.716 for Groups I–III).

Tables 1 and 2 show the mean age, testicular volume, and MR-E values of each group.

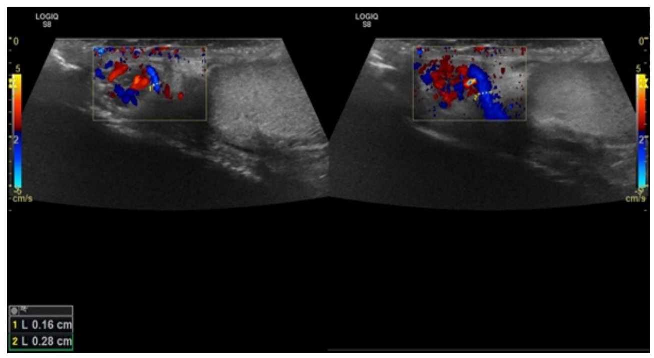

Figure 1. Doppler ultrasound examination showing the pampiniform plexuses and their measurements. The veins are colored in squares surrounded by a thin yellow line, and the image on the left shows a normal vein, and the image on the right shows a dilated vein (vein diameters 1.6 mm and 2.8 mm in the lower left corner, respectively).

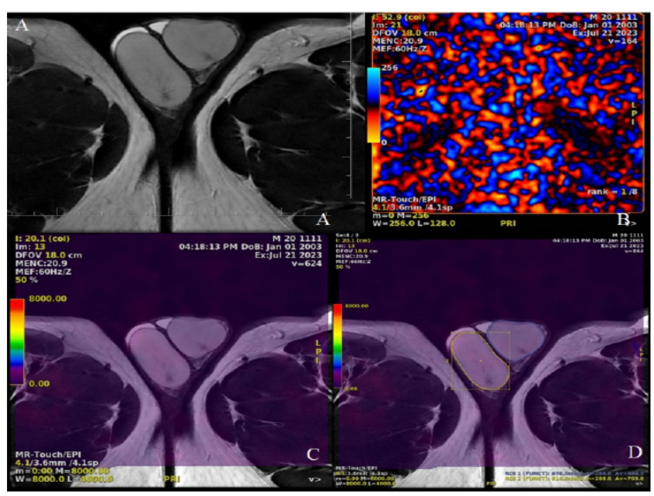

Figure 2. The top left image (A) shows axial spin echo T2 sequence, the right image (B) shows dynamic pressure color map. Bottom left image (C) shows an elastography fusion image, and the right image (D) shows stiffness measurement from the fusion image (the area within the thin yellow line is right testicular parenchyma, the area within the thin blue line is the left testicular parenchyma.)

Table 1. The mean age, testicular volume and mean MR-E values of each group

Group	Age (year)	Volume (mL)	MR-E value (Pa)
I	30.2 ± 9.1	15.1± 3.09 ml	5402.15 ± 223.12
II	33.6 ± 9.5	15 ± 4.31	6453.11 ± 198.13
III	34.4 ± 11	16.5 ± 4.45 ml	7947.12 ± 207.15

Results are shown as mean ± SD. MR-E: Magnetic resonance elastography, SD: Standard deviation, Pa: Pascals

Table 2. Binary comparison of each group for mean testicular volume findings

Group	I versus III	I versus II	II versus III
Mean testicular volume	15.1± 3.09 versus 16.5 ± 4.45	15.1± 3.09 versus 15 ± 4.31	15 ± 4.31 versus 16.5 ± 4.45
P	0,022	0,716	0,074

*P-value below 0.05 shows statistical significance, Values are presented as mean±SD in milliliters. SD: Standard deviation

Discussion

Elastography is a more contemporary, dependable, and non-invasive imaging method that provides information on histopathological changes in various tissues. It provides an invaluable quantitative evaluation of tissue stiffness and is crucial for diagnosing parenchymal disorders. The effect of varicocele on testicular parenchyma has only been studied in a small number of comparative investigations using MR-E [13,18].

The three groups (I, II, and III) in our study, which had 92 people and 184 testes, did not have any noticeable differences in mean ages. The mean testicular volume between groups I and III differed significantly. However, there were not many notable changes between Groups I and II or II and III. In our study, there was no appreciable distinction between the mean MR-E values of the three groups. Additionally, there was little variation in the mean MR-E values for binary comparisons. Additionally, neither the group mean MR-E value nor the mean testicular volume showed any obvious correlation. Our study demonstrated that the testicles of varicocele patients are smaller than those of healthy individuals.

In the literature, we could not find a study evaluating testicular parenchyma elastographically using MRI. Studies have examined the testes with US SWE [12-17]. In these studies, the stiffness value of the testis was measured in kPa. However, the MR-E device we used measures the stiffness value as Pa. kPa, which is obtained by dividing Pa by 1000, and the two units can be converted to each other.

One hundred individuals and 200 testes were evaluated in prospective research by Erdogan et al. that was quite similar [13] to this one. Testes from 50 patients with varicocele, 46 patients with contralateral healthy testes, and 104 healthy controls with normal testes were included in Groups A, B, and C, respectively. The average testicular volume for Group A, Group B, and Group C in this study was 13.43 ± 4.64 ml, 14.29 ± 3.82 ml, and 15.2 ± 4.13 ml, respectively. There was no discernible change in testicular volume among the three groups (P = 0.035, f = 3.424). In binary comparisons, only the difference between Groups A and C was found to be statistically significant (P = 0.014). Our findings are supported by statistical data on the mean testicular volume. In this study, the mean SWE values in Group A were 12.61 ± 6.23 kPa, in Group B were 9.23 ± 3.23 kPa, and 9.4 ± 4.30 kPa. They discovered a substantial difference in SWE values between the three groups, which is in contrast to our findings (P = 0.001). Additionally, testes with varicocele had significantly higher SWE values than healthy control testes (P = 0.001). In addition, the mean MR-E values and testicular volume for each group were not significantly correlated, which is comparable to our findings.

In a different prospective study, Dede et al. evaluated the association between varicocele, serum follicle-stimulating hormone levels, and elastography outcomes in 30 patients using acoustic radiation force impulse elastography [12]. This study only included 30 patients with left-sided varicoceles and 30 controls. Varicocele grade and testicular stiffness had a negative correlation. Patients with varicocele exhibited less testicular stiffness when the groups were compared. Turna and Aybar conducted a different study [18]. The testicles of 58 patients in a healthy control group and 116 patients with left-sided varicocele were examined. The varicocele-affected testes in this study had higher stiffness values than the contralateral healthy testes and the testes in the normal control group (P 0.001). Additionally, this study found no correlation between testicular stiffness and the severity of varicocele (r = 0.102, P = 0.423).

Limitations

Our study had several limitations. The most obvious limitation of this study is the small number of patients. Another limitation is the lack of histological evaluation of the testes which we included in the study. Third, despite the fact that the population in our study was larger than in earlier studies that have been published [12,13], we recommend future studies with larger sample sizes to confirm the efficacy of elastography in predicting testicular fibrosis and parenchymal damage. Owing to patient privacy, we did not assess interobserver variability. MR-E examination was performed on the entire testicular area; therefore, the sensitivity of the measurement may be reduced. In this study, the varicocele grade was not assessed. Although there have been several recent articles addressing the varicocele grading system, Dubin and Amelar developed it in 1970 when they investigated whether preoperative varicocele size was associated with changes in semen parameters. A grade 1 varicocele is only perceptible during the Valsalva maneuver, grade 2 varicoceles are felt at rest but not visible, and grade 3 varicoceles are clearly apparent [21].

Conclusion

According to our study, the mean testicular volume between the testes of the varicocele-affected group and those of the normal control group was considerably different. No correlation between MR-E values and testicular volume was found, nor an association between MR-E levels and varicocele were not found. However, additional studies with larger populations are needed to establish the efficacy of MR-E in predicting testicular parenchymal damage. Our findings imply that MR-E may assist

US SWE and gray-scale US in evaluating histopathologic alterations in the testis owing to varicocele. To reassess the impact of varicocele on testicular stiffness, nonsignificant results must be obtained despite the substantial results in the literature. These results might potentially be influenced by racial or cultural factors. We think that research including genetic factors and testicular parenchymal histology is required to verify the efficacy of MR-E.

Scientific Responsibility Statement

The authors declare that they are responsible for the article's scientific content including study design, data collection, analysis and interpretation, writing, some of the main line, or all of the preparation and scientific review of the contents and approval of the final version of the article.

Animal and Human Rights Statement

All procedures performed in this study were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments or comparable ethical standards.

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Conflict of Interest

The authors declare that there is no conflict of interest.

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